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COMPARISON OF MECHANICALLY BALLED MAGNESIUM WITH ATOMIZED MAGNESIUM FOR USE IN PYROTECHNIC COMPOSITIONS

JAMES A. CARRAZZA, JR.
DORIS E. MIDDLEBROOKS
SEYMOUR M. KAYE

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PICATINNY ARSENAL
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James A. Carrazza, Jr.
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Pyrotechnics Laboratory
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Picatinny Arsenal
Dover, N. J.

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OBJECT

To evaluate mechanically balled magnesium for use in pyrotechnic compositions as an alternate for the atomized magnesium currently required by Military Specification MIL-P-14067A, "Powders, Metals, Atomized (For Use in Ammunition)."

SUMMARY

Results of a variety of physical and chemical tests indicate that, with a few minor exceptions, Reade (balled) magnesium meets the requirements of Military Specification 14067-A for 30/50 mesh magnesium powder. The balled magnesium has been found to be less reactive than the currently prescribed atomized magnesium, both with water and as a result of exposure to high relative humidities, as determined by gas evolution, weight gain, and surface area measurements. Results of vacuum stability tests at 167°F and 230°F for thirty days indicate that the balled magnesium has greater stability than atomized magnesium; the thermochemical and sensitivity data for balled magnesium and atomized magnesium are comparable. In performance characteristics such as candlepower, burning rate, and luminous efficiency, similar results were obtained with the two materials. These results indicate that the Reade balled magnesium can be used as an alternate for Valley atomized 30/50 mesh magnesium in consolidated pyrotechnic compositions.

CONCLUSIONS AND RECOMMENDATIONS

Although the data derived in this study is based on an evaluation of samples from only one lot each of the balled and the atomized magnesium, the evaluation has resulted in the following conclusions. The balled magnesium essentially meets all the specification requirements for 30/50 mesh magnesium powder with the exception of the method of manufacture. The results of various reactivity tests indicate that it is less reactive than the atomized magnesium and has greater stability at elevated temperatures. No significant differences were found in the thermochemical analyses, heat of combustion determinations or reaction with water tests, and, according to Wilkaites (Ref 4), the two types of magnesium have comparable sensitivity values when incorporated with an oxidant. Finally, the performance characteristics of a typical pyrotechnic flare composition containing the balled magnesium compare favorably with those of a like composition containing atomized magnesium.

Test results indicate that balled magnesium can be used as an alternate for 30/50 mesh atomized magnesium in consolidated pyrotechnic composition.

It is recommended that the current Military Specification (14067A, Ref 1) be amended to include the use of balled magnesium as an alternate for atomized in the 30/50 mesh size.

It is further recommended that a program be initiated to evaluate the effects of long term high temperature storage on consolidated pyrotechnic compositions employing both balled and atomized magnesium blended with sodium nitrate and with other oxidants used in colored flare formulations.

INTRODUCTION

The current military specification (Ref 1) prescribes the use of atomized magnesium powder in ordnance applications. The term "atomized" means that the molten magnesium is dispersed into a spray, the droplets of which are allowed to solidify into spheres in a helium atmosphere under the primary influence of surface tension and are then classified to the applicable granulation. This requirement for spherical material, dating back to June 1949 in earlier versions of the above specification, was based on results of previous investigations in which compositions containing atomized magnesium were compared with compositions containing ground magnesium (JAN-M-382, Ref 2). These findings, as reported by Hart (Ref 3), revealed that ground magnesium has greater sensitivity, lower ignition temperatures, and greater reactivity than the currently prescribed atomized magnesium. Atomized magnesium is currently being produced by only one manufacturer, and therefore the present supply is quite limited.

Another method exists for the production of powdered magnesium. It consists of mechanically ball-milling irregularly chipped pieces of magnesium ingots, under an inert atmosphere, into spheres which are then screened to the applicable granulation. This balled magnesium, is currently being produced in quantity only in a granulation comparable to 30/50 mesh (350 ± 50 microns) atomized magnesium.

Mechanically balled magnesium in this granulation currently costs approximately $0.13 less per pound then atomized magnesium. The advantages of lower cost and also diversity in choice of manufacturers have made it mandatory that balled magnesium be evaluated as a possible alternate for atomized magnesium in pyrotechnic compositions.

Accordingly, a program was initiated to determine the physical and chemical properties of balled magnesium. This program was oriented to include comparisons of balled and atomized magnesium in terms of purity, moisture content, heat of combustion, vacuum stability, particle size distribution, particle shape and surface characteristics, density, surface area, and internal structure, as well as reactivity with moisture. Following these tests, a typical yellow flare composition was prepared and consolidated with both types of magnesium powder for evaluation of their performance characteristics.

Results of a study conducted by Olin Mathieson Chemical Corporation (Ref 4) indicated that both the atomized and the balled magnesium meet

the 30/50 mesh magnesium specification requirements for chemical analysis and distribution by sieve analysis. An investigation of the performance characteristics of a typical yellow composition in illuminant assemblies for the M301A2 81 mm illuminating projectile also gave comparable results for the two materials.

RESULTS

Photomicrographs of the various magnesium fractions at 35 x magnification and of single and cross sectioned particles at 75 x magnification are shown in Figures 1 through 4 (pp 30 through 35).

Results of sieve analyses of balled and atomized magnesium are compared to specification requirement in Table 1 (p 19) and the particle size distributions of the total samples and sieve fractions as determined by microscopic count, are shown in Table 2 (p 19).

The average particle size, as determined by air permeability, for the total samples and the sieve fractions of both the atomized and the balled magnesium are shown in Table 3 (p 20).

A comparison of the tapped and apparent densities of balled and atomized magnesium samples is made in Table 4 (p 20). Absolute density values for both types of magnesium samples, as determined before and after exposure to 70% relative humidity, are given in Table 5 (p 21).

Table 6 (p 21) compares the chemical analyses of the balled and atomized magnesiums with the specification requirement.

Moisture content data for the balled and atomized magnesium samples, as determined on the Electrodynamics moisture analyzer, is shown in Table 7 (p 22).

Hygroscopicity values for the balled and atomized magnesium samples, as determined by percent weight gain at 30, 50, and 70% relative humidity, are shown in Table 8 (p 23). Figure 5 (p 36) shows the percent weight gain at 70% relative humidity.

Reactivity with water as determined by gas evolution as a function of time at room temperature (approximately 25°C) and 167°F (76°C) is indicated in Table 9 (p 24) and Figures 6 and 7 (pp 37 and 38). Gas evolution as

determined by the vacuum stability test for thirty days at 167°F (76°C) and 230°F (110°C) is shown in Table 10 (p 25) and Figures 8 and 8 (pp 39 and 40).

Table 11 (p 26) gives specific surface area measurements for the various magnesium fractions as determined by the MIC-103 Numinco-Orr surface area pore volume analyzer before and after exposure to an atmosphere of 70% relative humidity.

Tables 12, 13, and 14 (pp 27, 28. and 29) compare the performance characteristics of samples of a typical consolidated pyrotechnic composition containing balled and atomized magnesium.

Differential thermal analysis curves for compositions prepared with the balled and atomized magnesiums are shown in Figures 10 and 11 and typical time-intensity traces for the same compositions is given in Table 13.

DISCUSSION OF RESULTS

One drum of 30/50 mesh magnesium powder from each manufacturer was selected for test. The drums used were identified as (1) Reade Manufacturing Company, 30/50 mesh magnesium powder, RMC-305, Drum 32, and (2) Valley Metallurgical Processing Company, 30/50 mesh magnesium powder, atomized, Contract DA-28-017-A-5-08365A, Drum 14. The Reade material was mechanically balled magnesium powder, while the Valley magnesium was atomized in accordance with Military Specification MIL-P-14067A.

Microscopic Examination

Results of microscopic examination as presented in Figure 1 (p 30) show some degree of deviation from sphericity for the atomized magnesium. Indentations or cavities appear regularly in each of the fractions studied and are revealed in the cross sectional and single particle photomicrograph at 75 × magnification (Figs 2 and 3, pp 32 and 33). Deviations from the spheroidal shape normally exhibited by balled magnesium are also apparent. These deviations (see Fig 4, p 34) increase with decreasing particle size while particle elongation becomes more apparent. No cavities are evident in the cross sectional photomicrograph; however, an irregular roughness of the surface, which is probably due to the method of manufacture, is apparent (Figs 2 and 3).

Particle Size Distribution

The particle size distributions were determined by sieve analyses of thiefed samples of both materials, in accordance with the procedure detailed in MIL-P-14067A (Ref 1). The results (Table 1) indicate that both materials meet the specification requirements, the atomized magnesium containing coarse and fine fractions which are substantially absent in the balled magnesium. The size distribution of the atomized material is thus significantly wider (10% at the coarse end and 15% at the fine end) than that of the balled magnesium.

Particle size distributions by microscopic count (Ref 5) were conducted on the original materials as well as on 20/30, 30/40, 40/50, and 50/60 sieve fractions to determine whether differences exist within these fractions which may effect the performance characteristics. The results (Table 2) show a fair similarity between the averages (geometric means) and the ranges for the two materials in the original (30/50)mesh size and the coarsest (20/30)fraction. This comparability becomes poorer with decreasing particle size, the balled magnesium being larger. This difference can be attributed to the elongated shape or the greater deviation from the spheroidal shape which increases with decreasing particle size, as the photomicrographs (Fig 4) of the balled magnesium particles indicate.

Average Particle Size

The average particle diameter of the original materials and of all of their fractions was determined using the Picatinny Arsenal particle sizer (Ref 5). The results indicate (Table 3) that the two types of magnesium have closely similar average particle diameters in all fractions tested. MIL-P-14067A requires that the 30/50 magnesium have an average particle size, determined by air permeability, falling within the 350 ± 50-micron range. The original balled material exceeded the upper limit by 4 microns, which is not considered significant, as it falls within experimental error.

Apparent and Tapped Densities

Apparent and tapped density tests were performed on both the original magnesium samples and the fractions sieved from them. The apparent densities were determined in accordance with the procedure described in MIL-P-14067A (Ref 1), and the tapped densities by the procedure detailed in the Pyrotechnics Laboratory Handbook of Particle Size Procedures (Ref 5).

The results (Table 4) indicate that both the apparent and tapped density values for the atomized fractions are slightly higher than those obtained with the balled fractions. MIL-P-14067A specified a minimum apparent density of 1.0 g/ml for the 30/50 mesh material. The original balled 30/50 mesh magnesium is 0.98 g/ml, or 0.02 g/ml below the requirement, which may be due either to the elongated shape or to experimental error. Kristal (Ref 6) has reported that apparent density values as low as 0.95 g/ml should be considered acceptable.

Absolute Densities

Absolute densities were determined for all test samples both after storage under ambient conditions and after storage at high relative humidity (70% relative humidity for 30 days).

These measurements, not required by the specification, were made for two reasons: (1) to determine the amount of oxide or hydroxide coating on the original materials, and (2) to determine the reactivity of each sample with moisture in the air. Since the density of magnesium oxide (3.58 g/ml) and also that of magnesium hydroxide (2.38 g/ml) are greater than that of magnesium (1.74 g/ml), the absolute density values would be a true measure of the amount of oxide or hydroxide present. The absolute density measurements were made by pycnometer at 25°C using acetone, A.C.S. grade (Ref 7).

The results (Table 5) reveal that, after ambient storage, the balled and atomized magnesium samples have closely similar absolute density values, such slight differences as exist being attributable to experimental error. Since the values obtained are not above the absolute density value of magnesium (1.74 g/ml) the amount of oxide or hydroxide coating cannot be determined.

After storage at 70% relative humidity for 30 days, the balled magnesium showed essentially no change in absolute density, indicating that it does not react with moisture. The atomized magnesium, however, showed an increase, particularly marked in the 20/30 fraction, indicating greater reactivity with moisture than had been shown by the balled samples. This greater reactivity was also indicated by a less metallic appearance and by a grey discoloration evident in all sieve fractions but most marked in the 20/30 mesh fraction.

The greater reactivity of the atomized samples is attributed to the presence of cavities, which are evident in the photomicrographs (Figs 1, 2, and 3).

Although reactivity is evident in the atomized material after storage at 70% relative humidity, the true amount of oxide or hydroxide present could not be determined from the values obtained.

Chemical Analysis

A chemical analysis (Ref 8) was conducted on the original samples of balled and atomized magnesium powders in accordance with MIL-P-14067A. The results (Table 6) indicate that both the balled and the atomized powders are well within the specification requirement for 30/50 mesh. Since the method of production of the balled magnesium is mechanical, an analysis for grease and/or oil content was also conducted. No measurable quantity of grease or oil was found in either the balled or atomized samples (Table 6 and Ref 9).

Moisture Content

Both the balled and the atomized magnesium samples meet the specification requirement for total volatile content. However, moisture content was also determined electrolytically using the Consolidated Electrodynamics moisture analyzer on the the original materials as received as well as on the 20/30, 30/40, 40/50, and 50/60 sieve fractions. The data obtained (Ref 10 and Table 7) indicates that the balled magnesium has a greater moisture content than the atomized magnesium. No correlation was found between this data and the data on total volatiles as determined in the chemical analysis (Table 6), which should include any moisture content.

Reactivity with Moisture

The reactivity of the magnesium with moisture is an important parameter since minute amounts of water are inadvertently incorporated in magnesium-fueled flares and signals because of moisture content or hygroscopicity of ingredients. This moisture can react with the magnesium on storage, both degrading the magnesium to its hydroxide and releasing gases which are capable of building up pressure sufficient to burst hermetically sealed containers, as is indicated by the work of H. Eppig (Ref 11) and the following equation:

$$Mg + 2\,HOH \longrightarrow Mg\,(OH)_2 + H_2\uparrow$$

Accordingly, a study was undertaken to determine the relative reactivity of balled and atomized magnesium with moisture.

The first phase of the study consisted of exposing the original 30/50 mesh materials and their respective sieve fractions to 30%, 50%, and 70% relative humidities at 30°C, and determining the percentage weight increase as a function of time for up to 31 days of exposure. The weight increases would be a result of magnesium hydroxide formation or a measure of reactivity. The data (see Table 8 and Ref 12) indicates that both the balled and the atomized samples are essentially nonreactive, with maximum weight increases of only 0.01% after 31 days at 30% relative humidity. Under 50% relative humidity conditions, the atomized samples showed increased reactivity, the weight increase being particularly marked for the 20/30 mesh fraction. Under 70% relative humidity conditions, all of the atomized fractions show marked weight increases compared with like balled fractions, the atomized 20/30 mesh fraction being particularly reactive.

A comparison of the percent weight gain of the different fractions at the various relative humidity levels after thirty-one days of 30°C exposure follows:

	Relative Humidity, %		
	30	50	70
Balled Magnesium			
Total samples (30/50 mesh)	0	*	0.04
20/30 mesh	0	0.01	0.01
30/40 mesh	0	*	0.02**
40/50 mesh	0	0.01	0.06
50/60 mesh	*	0	0.04
Atomized Magnesium			
Total samples (30/50 mesh)	0	0.01	0.16
20/30 mesh	0	0.07	0.60
30/40 mesh	0.01	0.01	0.12
40/50 mesh	*	*	0.07
50/60 mesh	0.01	0.01	0.07

*Loss in weight.

**25th day value.

It is interesting to note that the atomized 20/30 mesh fraction also had a density value of 1.99 g/ml after 31 days of conditioning at 70% relative humidity (see Table 5). This density value was far greater than those obtained for the other atomized or balled fractions stored under identical relative humidity conditions, and reflects increased formation of magnesium hydroxide, which is indicative of increased reactivity.

A second phase of this study was to determine the degree of reactivity of the magnesium fractions with water by measuring the amount of gas evolved. The results (Table 9, Figs 6 and 7, and Ref 13) indicate that the atomized magnesium is more reactive than the balled. At 167°F (76°C), all atomized samples exceeded the capacity of the apparatus (producing 11 ml of gas within a 2-hour interval). The balled magnesium samples did not reach this limit until after 16 hours had elapsed. At room temperature, all atomized magnesium samples yielded 11 ml of gas in the first 16 hours. The balled magnesium, however, required much longer periods ranging from 12 days for the 20/30 sieve fraction to 27 days for the 30/40 sieve fraction to produce 11 ml of gas. The total time required for each of the fractions to yield 11 ml of gas is shown in the following table:

	Reaction Time for Evolution of 11 Ml of Gas, hr	
	Room Temperature (25°C)	76°C
Balled Magnesium		
Total samples (30/50 mesh)	480	16
20/30 mesh	288	16
30/40 mesh	648	16
40/50 mesh	472	16
50/60 mesh	480	16
Atomized Magnesium		
Total samples (30/50 mesh)	16	1
20/30 mesh	16	1
30/40 mesh	16	2
40/50 mesh	16	1.5
50/60 mesh	16	1.5

The third and final phase of the reactivity study consisted of gas evolution determinations for samples that had been stored at elevated temperatures. This was accomplished by using the standard vacuum stability apparatus and method as

described by Clear (Ref 14). The samples were kept under surveillance for thirty days at temperatures of 167°F and 230°F. The results, (Table 10, Figs 8 and 9, and Ref 13) indicate that the balled magnesium samples evolve significantly less gas than the atomized samples as a function of time at elevated temperatures. The gases evolved can be attributed to entrapment of gases during the manufacturing process, and/or to entrapment of moisture not removed by desiccant drying or decomposition of a hydroxide film on the surface of the magnesium. The results at the conclusion of the 30-day surveillance period were as follows:

	30-Day Vacuum Stability Results	
	Ml Gas at 165°F	Ml Gas at 230°F
Balled Magnesium		
Total samples (30/50 mesh)	0.07	0.17
20/30 mesh	0.07	0.20
30/40 mesh	0.06	0.20
40/50 mesh	0.06	0.20
50/60 mesh	0.10	0.17
Atomized Magnesium		
Total samples (30/50 mesh)	0.33	0.58
20/30 mesh	0.70	0.62
30/40 mesh	0.46	0.63
40/50 [illegible]	0.36	0.66
50/60 mesh	0.18	0.54

Surface Area Measurements

Surface area measurements were conducted on the total sample (30/50 mesh) and on 20/30, 30/40, 40/50, and 50/60 sieve fractions of both balled and atomized magnesium before and after exposure to 70% relative humidity for 30 days. The purpose of obtaining these measurements was to compare the specific surface areas of the two types of magnesium and to determine the effects of moisture on the surface areas. The results (Table 11 and Ref 15) indicate that the total (30/50 mesh) sample of atomized magnesium has a surface area approximately four times as great as that of the total (30/50 mesh) sample of balled magnesium. After exposure to an

atmosphere of 70% relative humidity for 30 days, the atomized total sample (30/50) increased in surface area twelve times (from 6,440 cm^2/g to 77,900 cm^2/g). The balled magnesium, however, only showed an eightfold increase (from 1,560 cm^2/g to 12,500 cm^2/g) after the same exposure. The increase in surface area after exposure to moisture is attributed to hydroxide formation and is considered a measure of reactivity.

The higher degree of reactivity shown by the Valley magnesium correlates with previous reactivity data which indicates that atomized magnesium is more reactive than balled magnesium. This greater reactivity may be a consequence of greater surface area.

The surface area measurements of the several sieve fractions all show the same trend. This is especially evident in the case of the 20/30 mesh atomized fraction, which reveals a 49-fold increase in surface area after exposure to 70% relative humidity for 30 days (from 8,820 cm^2/g to 432,000 cm^2/g).

The tendency of the surface area of these materials to increase with increasing particle size contradicts the normal expectation that the surface area will increase with decreasing particle size. These anomalous results are attributed to internal particle porosity, the porosity being more pronounced in larger particles. Evidence of the particle porosity is indicated by the photomicrographs (Fig 3).

Thermochemical Analysis

Differential thermal analyses by the method of Gordon and Campbell (Ref 16) were conducted on both the balled and atomized magnesium in a typical pyrotechnic blend (56/36.3/7.7 magnesium/sodium nitrate/Laminac). The results (see Figs 10 and 11) revealed no significant difference in either the ignition temperature (approximately 500°C) or the endotherms and exotherms obtained.

Heat of reaction determinations conducted on the above compositions failed to show any significant differences in calories per gram or volume of gas (ml/g) produced for either sample (Ref 17).

	Heat of Reaction, cal/g	Gas Volume, ml/g
Balled magnesium/sodium nitrate/Laminac	1444.0	80.1
Atomized magnesium/sodium nitrate/Laminac	1485.5	79.4

Heat of combustion determinations on both magnesium samples failed to reveal any significant difference in calories per gram (Ref 18).

	Heat of Combustion cal/g
Balled	5985.4
Atomized	6022.0

Sensitivity

Sensitivity experiments were conducted by the Olin Mathieson Chemical Corporation (Ref 4) on samples of both atomized and balled magnesium in a cured illuminant mix (not given) with oxidizer present. The following results were reported:

Impact Sensitivity – Bureau of Mines, 2 kg weight. Neither sample fired at a drop of 80 cm. This is the highest range of the equipment.

Electrostatic Sensitivity – Bureau of Mines, RI-403D. This test was conducted at .05 mfd and 5000 volts. No fires were observed for either sample in five (5) trials.

Ignition Temperature – Ignition time at 425°C was about five (5) seconds for both materials. Their ignition temperatures are considered equivalent.

Performance Characteristics

Performance characteristics of identical pressed pyrotechnic compositions containing balled and atomized magnesium were compared. Three separate tests were conducted with two different lots of atomized magnesium and one lot of balled magnesium.

The results (Tables 12, 13, and 14, pp 27, 28, and 29) fail to show any significant differences between the balled and the atomized magnesiums in luminous intensity, burning rate, or luminance efficiency values. The coefficients of variation, while not consistent from test to test, are small in all cases.

No differences were detected by visual observation of the burning flares; however, typical intensity-time traces (Fig 13) indicate that the balled magnesium composition burns with less fluctuation in the luminous intensity profile than the atomized magnesium composition.

EXPERIMENTAL PROCEDURE

Testing

Particle size distributions were determined by the method detailed in paragraph 4.4.6 of MIL-P-14067A (Ref 1) as well as by microscopic count as described in Chapter XV of the Pyrotechnics Handbook (Ref 5).

Average particle diameters were determined on the Picatinny Arsenal particle sizer by the air permeability method in accordance with Military Standard MIL-STD-1233, method 200 (Ref 19).

Apparent and tapped densities were determined by methods described in Chapter XV of the Pyrotechnics Handbook (Ref 5).

Absolute density determinations were carried out by using a pycnometer at 25°C with ACS grade acetone as the solvent (Ref 7).

The chemical analyses were performed in accordance with the method described in MIL-P-14067A and the moisture content was determined by the Electrodynamics moisture analyzer in accordance with SOP-281-140.

Hygroscopicity determinations were conducted at 30%, 50%, and 70% relative humidity with 7-8 grams of material. Weight gain was recorded biweekly for a period of thirty days.

Reactivity with moisture tests were conducted on samples predried over phosphorus pentoxide. Equal amounts of water and magnesium (2.5 grams water/2.5 grams magnesium) were allowed to react in the standard vacuum stability apparatus (Ref 10) at room temperature (25°C) and at 167°F (76°C). Gas evolution was measured and recorded over a period of thirty days or till the sample evolved 11 ml of gas, the capacity of the apparatus.

Gas evolution was determined by vacuum stability with a 2.5-gram sample dried over phosphorus pentoxide. Determinations were made daily in accordance with a method described by A. J. Clear (Ref 14).

Surface area measurements were conducted by Edgewood Arsenal (Ref 15) using the Numinco-Orr MIC-103 surface area – pore volume analyzer.

Heats of combustion were determined in accordance with the procedure described in Parr Manual 130.

Heat of reaction tests were conducted in accordance with the procedure described in Report 62-VE6-25.

Materials

Magnesium, atomized, Drum 14, DA-28-017-A5-0836-5A, purchased from Valley Metallurgical Corporation as 30/50 mesh in accordance with Specification MIL-P-14067A. Average particle size as determined by Picatinny Arsenal particle size apparatus was 386.9 microns.

Magnesium, atomized, Drum 3, DA-28-019A-A-5-0729IA, purchased from Valley Metallurgical Corporation as 30/50 mesh in accordance with Specification MIL-P-14067A. Average particle size as determined by Picatinny Arsenal particle size apparatus was 400 microns.

Magnesium, "balled," RMC-305, Drum 32, supplied by the Reade Manufacturing Company. Average particle size as determined by the Picatinny Arsenal particle size apparatus was 404.6 microns.

Sodium nitrate, double refined, Class 2, purchased from Davies Nitrate Company. Average particle size 34 microns, as determined by Fisher sub sieve sizer in accordance with Specification PA-PD-495.

Laminac 4116, in accordance with Specification PA-PD-2353, purchased from American Cyanamid Corporation.

Preparation of Blends

The illuminating compositions were prepared in a Lancaster LW Model blender in accordance with procedure described in SOP-PC-4.

Loading

Flares were consolidated using five increments of 50 grams each at a pressure of 5000 psi (3.47 ton dead load) into 1.33-inch-ID, paraffin wax coated, thin-walled (1/32 inch) kraft paper cases. The first increment contained an additional 5 grams of igniter composition FF-101-L and the last increment an additional 5 grams of Laminac-coated fireclay. Charge height was 6.2 inches (143 cc) and charge density was 1.75 cm/cc for the FY1230 and FY1230A compositions, while charge height was 6.4 inches (145 cc) and charge density 1.72 cm/cc for the FY-1231 composition.

Luminous Intensity Testing

The time-intensity characteristics of the flare compositions were determined statically under ambient pressure. The flares were burned in a face-up vertical position. All tests were conducted in the Pyrotechnics Laboratory's flare tunnel. Instrumentation consisting of a photocell-recorder combination was used to pick up the light emission and burning time.

REFERENCES

1. MIL-P-14067-A (MU), *Powders, Metal, Atomized (For Use in Ammunition),* 16 May 1955

2. Jan-M-382, *Magnesium Powder (For Use in Ammunition),* 28 August 1946

3. D. Hart and H Eppig, *Long Range Research on Pyrotechnics: Burning Characteristics of Binary Mixtures. Report No. 1,* Picatinny Arsenal Technical Report 1669, 16 October 1947

4. N. J. Wilkaitis, *Mechanically Balled Magnesium for Reade Manufacturing Company,* Olin Mathieson Chemical Corporation, 15 February 1965

5. "Particle Size Procedures," *Pyrotechnics Handbook,* Chapter XV, The McGraw-Hill Technical Writing Service (In Press)

6. J. Kristal, *A Comparison Study of Apparent and Tapped Densities of Atomized Magnesium, Aluminum and Aluminum-Magnesium Alloy Metal Powders,* Pyrotechnics Laboratory Information Report 4, April 1963

7. *Operations and Maintenance Manual for the Sharples Micromerograph,* Chapter 3, Sharples Corporation Research Laboratories, Bridgeport, Penn.

8. Picatinny Arsenal Laboratory Report 65-VG1-103, Propellants Research Branch, 4 October 1965

9. Picatinny Arsenal Laboratory Report 66-VG1-8, Propellants Research Branch, 12 January 1966

10. Moisture Determination Results, Job Order 4067-01-004(370), Loading Branch, I. S. D., Picatinny Arsenal, 18 August 1965

11. H. Eppig, *Effects of Moisture on the Stability of Pyrotechnic Compositions, Report No. I,* Picatinny Arsenal Technical Report 1661, 18 August 1947

12. Picatinny Arsenal Laboratory Report AL-P-223-65, Analytical Chemistry Branch, 4 August 1965

13. Picatinny Arsenal Laboratory Report AL-S-134-65, Analytical Chemistry Branch, 8 December 1965

14. Clear, A. J., Standard Laboratory Procedures for Sensitivity, Brisance and Stability of Explosives, Picatinny Arsenal Technical Report FRL-TR-25, January 1961; revised as PATR 3278, December 1965, same author.

15. Edgewood Arsenal Report *Surface Area Measurement of Magnesium Powders,* Letter dated 21 March 1966

16. S. Gordon and C. Campbell, "Differential Thermal Analysis of Inorganic Compounds," *Analytical Chemistry 27:* 1102 (July 1955)

17. Picatinny Arsenal Laboratory Report 63, Calorimetry Laboratory, 3 November 1965

18. Picatinny Arsenal Laboratory Report 56, Calorimetry Laboratory, 15 September 1965

19. MIL-STD-1233, Method 200, *Procedures for Determining Particle Size, Particle Size Distribution and Packed Density of Powdered Materials,* 21 March 1962

TABLE 1

Sieve analysis of balled and atomized (30/50 mesh) magnesium as compared to specification requirement

U. S. Standard Sieve	Percent Passing Through, by Weight: Balled, Run 1	Balled, Run 2	Atomized, Run 1	Atomized, Run 2	MIL-P-14067A Requirement
20	100.0	100.0	99.5	99.5	95 min
30	99.4	99.5	88.1	87.5	85 min
50	1.2	1.2	11.3	7.9	40 max
60	0.3	0.3	8.5	5.5	25 max
100	0.0	0.0	1.2	0.3	5 max

TABLE 2

Microscopic count particle size distribution of balled and atomized magnesium

Magnesium Fractions	Nominal Particle Size, Range, in microns	Particle Size Data by Microscopic Count, microns — Balled: Average, Geometric Mean	Balled: Range 16-84% Points	Atomized: Average Geometric Mean	Atomized: Range 16-84% Points
Original (30/50 mesh)	297-590	495	385-640	493	365-670
20/30 mesh	590-840	780	690-880	765	670-890
30/40 mesh	420-590	650	515-799	550	460-660
40/50 mesh	297-420	485	385-610	370	320-430
50/60 mesh	250-297	410	325-520	290	173-322

TABLE 3

Average particle diameter of balled and atomized magnesium *

Magnesium Fractions	Balled	Atomized
Original, 30/50 mesh	404.6	386.9
20/30 mesh	660.6	651.0
30/40 mesh	495.1	487.7
40/50 mesh	387.1	395.8
50/60 mesh	249.3	268.4

*As determined by air permeability.

TABLE 4

Apparent and tapped densities of balled and atomized magnesium

Magnesium Fractions	Balled, g/ml		Atomized, g/ml	
	Apparent	Tapped	Apparent	Tapped
Original, 30/50 mesh	0.98	1.08	1.06	1.12
20/30 mesh	1.02	1.09	1.03	1.08
30/40 mesh	0.98	1.08	1.03	1.09
40/50 mesh	0.96	1.08	1.01	1.08
50/60 mesh	0.94	1.05	1.03	1.09

TABLE 5

Absolute density of balled and atomized magnesium after ambient and 70% relative humidity storage for 30 days

Magnesium Fractions	Balled, g/ml Ambient Storage	Balled, g/ml Conditioned at 70% RH for 30 days	Atomized, g/ml Ambient Storage	Atomized, g/ml Conditioned at 70% RH for 30 days
Original, 30/50 mesh	1.70	1.73	1.70	1.73
20/30 mesh	1.71	1.73	1.70	1.99
30/40 mesh	1.72	1.74	1.70	1.76
40/50 mesh	1.73	1.73	1.70	1.78
50/60 mesh	1.73	1.72	1.70	1.73

TABLE 6

Chemical analysis (%) of balled and atomized magnesium as compared to specification requirements

Determination	Balled	Atomized	MIL-P-14067A Requirements
Free metallic magnesium	99.6	100.7	98.0 min
Total magnesium	99.9	100.2	No requirement
Volatiles at 105°C	<0.01	<0.01	0.1 max
Carbides	<0.004	<0.004	0.004 max
Magnetic iron	0.017	<0.001	0.05 max
Alloy iron as Fe	<0.05	<0.05	0.05 max
Zinc	0.1	0.04	1.5 max
Other impurities	0.2	0.0	0.3 max
Grease and/or oil	0.0	0.0	No requirement

TABLE 7

Percentage moisture as determined by Electrodynamics moisture analyzer

Magnesium Fractions	Balled Magnesium	Atomized Magnesium
Original, 30/50 mesh	0.16	0.12
20/30 mesh	0.15	0.06
30/40 mesh	0.23	0.01
40/50 mesh	0.14	0.12
50/60 mesh	0.16	0.12

TABLE 8

Percent weight gain of balled and atomized magnesium fractions after exposure to 30%, 50%, and 70% relative humidities

	Balled					Atomized				
Sample No.:	1	2	3	4	5	1	2	3	4	5
Time, Days / Fraction:	Total Sample	20/30	30/40	40/50	50/60	Total Sample	20/30	30/40	40/50	50/60
Hygroscopicity at 30% RH and 30°C										
1	0	0	0	0.01	*	*	*	*	*	*
4	0.01	0	0.01	0.01	*	0	*	*	*	*
8	0	0	0	0	*	*	*	*	*	0
12	*	0.01	0.01	0.01	*	0	*	*	*	0
15	0	0	0.01	0.01	*	0	*	*	*	0
18	0	0.01	0	0	*	*	0	*	*	0
21	0	0	0	0	*	0	0	*	*	0.01
25	0.01	0.01	0.01	0.01	*	0	0	*	*	0.01
31	0	0	0	0	*	0	0	0.01	*	0.01
Hygroscopicity at 50% RH and 30°C										
1	0	0	0	0	*	0.01	0.03	0.01	0	0
4	0	0	0	0	0	0.01	0.06	0.01	0.01	0.01
8	0	0	0	0	*	0.01	0.06	0.01	0.01	0.01
12	0	0	0	0	0	0.01	0.06	0.01	0.01	0.01
15	0	0	0	0	0	0.01	0.13	0.01	0.01	0.01
18	*	0	*	0	0	0.01	0.09	0.01	0.01	0.01
21	*	0	*	0.01	0	0.01	0.09	0.01	*	0.01
25	*	0.01	*	0.01	0.01	0.01	0.06	0.01	*	0.01
31	*	0.01	*	0.01	0	0.01	0.07	0.01	*	0.01
Hygroscopicity at 70% and 30°C										
1	*	*	0.01	0	0	0.10	0.31	0.03	0.01	0.01
4	0.01	*	0	0.02	0.02	0.09	0.58	0.06	0.03	0.03
8	0.02	*	0.01	0.02	0.02	0.12	0.68	0.08	0.04	0.04
12	0.02	*	0.01	0.03	0.02	0.13	0.71	0.10	0.04	0.04
15	0.03	*	0.01	0.01	0.03	0.15	0.73	0.11	0.05	0.05
18	0.03	*	0.01	0.04	0.03	0.14	0.64	0.11	0.06	0.05
21	0.03	**	0.02	0.05	0.03	0.15	0.65	0.11	0.06	0.06
25	0.04	0.01	0.02	0.06	0.04	0.16	0.66	0.13	0.07	0.07
31	0.04	0.01	**	0.06	0.04	0.16	0.60	0.12	0.07	0.07

*Signifies a loss in weight.

**Means no data obtained.

TABLE 9

Reactivity with water (ml of gas produced as a function of time)

	Total Sample	20/30 Mesh	30/40 Mesh	40/50 Mesh	50/60 Mesh
	ATOMIZED MAGNESIUM AT ROOM TEMPERATURE (25°C)				
16 hours	11+	11+	11+	11+	11+
	ATOMIZED MAGNESIUM AT 76°C (167°F)				
1 hours	11+	11+	–*	–	–
1.5 hours	–	–	–	11+	11+
2 hours	–	–	11+	–	–
	BALLED MAGNESIUM AT ROOM TEMPERATURE				
1 day	3.6	5.2	3.7	4.0	4.2
2 days	4.7	7.0	4.8	–	–
4 days	–	–	–	5.9	6.3
5 days	5.8	8.5	5.8	6.4	6.7
6 days	6.1	8.9	6.2	6.9	7.2
7 days	6.5	9.6	6.5	7.5	7.8
8 days	7.0	10.3	7.0	7.9	8.3
9 days	7.3	10.4	7.3	–	–
11 days	–	–	–	9.1	8.9
12 days	8.3	11.0	8.0	9.4	9.5
13 days	8.4	–	8.2	9.8	9.9
14 days	8.5	–	8.7	10.2	10.3
15 days	9.5	–	9.0	10.2	10.3
16 days	9.1	–	9.2	–	–
19 days	10.1	–	–	11.2	10.9
20 days	10.3	–	10.1	–	11.5
21 days	–	–	10.3	–	–
22 days	–	–	10.5	–	–
23 days	–	–	10.2	–	–
26 days	–	–	10.9	–	–
27 days	–	–	11.1	–	–
	BALLED MAGNESIUM AT 76°C				
16 hours	11+	11+	11+	11+	11+

*–Means no data obtained.

TABLE 10

Vacuum stability of balled and atomized magnesium during thirty days storage (ml of gas)

	Balled Magnesium									
	76°C (167°F)					110°C (230°F)				
Days / Fractions:	Total Sample	20/30	30/40	40/50	50/60	Total Sample	20/30	30/40	40/50	50/60
1	0.11	0.11	0.10	0.11	0.15	0.15	0.19	0.18	0.16	0.16
2	–*	–	–	–	0.23	0.16	0.17	0.13	0.19	0.17
3	–	–	–	–	0.12	0.14	0.15	0.17	0.17	0.15
4	0.08	0.06	0.04	0.08	0.11	0.13	0.14	0.17	0.17	0.15
5	0.09	0.08	0.06	0.10	–	–	–	–	–	–
6	0.08	0.10	0.06	0.09	–	–	–	–	–	–
7	0.07	0.06	0.04	0.07	0.13	0.11	0.13	0.14	0.17	0.11
8	0.08	0.06	0.03	0.08	0.12	0.13	0.14	0.15	0.13	0.12
9	–	–	–	–	0.10	0.13	0.14	0.15	0.15	0.12
10	–	–	–	–	0.11	0.15	0.18	0.18	0.15	0.12
11	0.07	0.06	0.05	0.08	0.09	0.16	0.18	0.18	0.18	0.18
12	0.06	0.06	0.05	0.08	–	–	–	–	–	–
13	0.06	0.06	0.02	0.08	–	–	–	–	–	–
14	0.06	0.07	0.05	0.08	0.09	0.13	0.17	0.17	0.18	0.13
15	0.03	0.04	0.03	0.05	0.11	0.13	0.16	0.15	0.16	0.13
16	–	–	–	–	0.10	0.22	0.18	0.17	0.14	0.16
17	–	–	–	–	0.10	0.15	0.16	0.17	0.18	0.14
18	0.02	0.03	0.02	0.06	0.09	0.18	0.21	0.20	0.17	0.18
19	0.02	0.05	0.03	0.06	–	–	–	–	–	–
20	0.03	0.07	0.03	0.06	–	–	–	–	–	–
21	0.05	0.05	0.04	0.06	–	0.13	0.18	0.15	0.19	0.14
22	0.06	0.03	0.04	0.06	0.09	0.15	0.17	0.16	0.15	0.13
23	–	–	–	–	0.07	0.18	0.20	0.19	0.15	0.16
24	–	–	–	–	0.10	0.18	0.20	0.21	0.19	0.17
25	–	–	–	–	0.09	0.19	0.21	0.21	0.20	0.18
26	0.03	0.03	0.03	0.05	–	–	–	–	–	–
27	0.03	0.03	0.03	0.04	–	–	–	–	–	–
28	0.03	0.05	0.04	0.08	0.14	0.17	0.21	0.19	0.19	0.18
29	0.03	0.03	0.04	0.06	0.09	0.19	0.22	0.22	0.20	0.18
30	–	–	–	–	0.10	0.17	0.20	0.20	0.20	0.17
31	–	–	–	–	–	–	–	–	–	–
32	0.07	0.07	0.06	0.06	–	–	–	–	–	–

	Atomized Magnesium									
	76°C (167°F)					110°C (230°F)				
Days / Fractions:	Total Sample	20/30	30/40	40/50	50/60	Total Sample	20/30	30/40	40/50	50/60
1	0.27	0.05	0.15	0.47	0.26	0.20	0.11	0.11	0.14	0.16
2	–	–	–	0.49	0.27	0.24	0.15	0.18	0.18	0.22
3	–	–	–	0.46	0.25	0.25	0.15	0.19	0.21	0.26
4	0.33	0.21	0.19	0.38	0.24	0.24	0.19	0.18	0.19	0.17
5	0.34	0.20	0.20	–	–	–	–	–	–	–
6	0.32	0.29	0.25	–	–	–	–	–	–	–
7	0.30	0.25	0.22	0.40	0.25	0.41	0.21	0.26	0.27	0.26
8	0.29	0.19	0.19	0.40	0.25	0.39	0.28	0.32	0.33	0.32
9	–	–	–	0.42	0.25	0.40	0.29	0.32	0.34	0.33
10	–	–	–	0.44	0.25	0.46	0.33	0.38	0.40	0.44
11	0.29	0.25	0.20	0.43	0.26	0.42	0.28	0.33	0.35	0.33
12	0.29	0.25	0.20	–	–	–	–	–	–	–
13	0.29	0.25	0.24	–	–	–	–	–	–	–
14	0.31	0.30	0.27	0.40	0.23	0.40	0.27	0.42	0.34	0.33
15	0.33	0.34	0.32	0.36	0.23	0.40	0.28	0.33	0.35	0.33
16	–	–	–	0.36	0.24	0.42	0.31	0.36	0.38	0.36
17	–	–	–	0.36	0.22	0.42	0.31	0.37	0.39	0.35
18	0.30	0.38	0.34	0.38	0.22	0.46	0.34	0.38	0.44	0.37
19	0.30	0.34	0.35	–	–	–	–	–	–	–
20	0.30	0.38	0.38	–	–	–	–	–	–	–
21	0.30	0.42	0.38	–	–	0.51	0.39	0.44	0.48	0.43
22	0.31	0.52	0.39	0.35	0.18	0.51	0.38	0.42	0.48	0.42
23	–	–	–	0.34	0.15	0.52	0.40	0.44	0.48	0.43
24	–	–	–	0.35	0.15	0.53	0.43	0.46	0.51	0.46
25	–	–	–	0.33	0.17	0.56	0.47	0.49	0.56	0.48
26	0.30	0.59	0.40	–	–	–	–	–	–	–
27	0.28	0.60	0.42	–	–	–	–	–	–	–
28	0.30	0.68	0.4[illegible]	0.36	0.22	0.52	0.52	0.54	0.59	0.51
29	0.29	0.66	0.49	0.34	0.16	0.56	0.55	0.58	0.64	0.54
30	0.33	0.70	0.46	0.36	0.18	0.58	0.62	0.63	0.66	0.54
31	–	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–

*–Means no data obtained.

TABLE 11

Effects of high relative humidity (70%) on specific surface area (cm^2/g) of balled and atomized magnesium

Sieve Fractions	Calculated Area* Balled	Calculated Area* Atomized	Specific Surface Area of Unexposed Controls Balled**	Specific Surface Area of Unexposed Controls Atomized**	Specific Surface Area of Unexposed Controls Ratio Atomized:Balled	Specific Surface Area of Samples Exposed to 70% RH for 30 Days Balled**	Specific Surface Area of Samples Exposed to 70% RH for 30 Days Atomized***	Specific Surface Area of Samples Exposed to 70% RH for 30 Days Ratio Atomized:Balled
Total (30/50)	85.0	89.5	1,560	6,440	4.1:1	12,500	77,900	6.2:1
20/30 Mesh	34.4	52.9	3,570	8,820***	2.5:1	31,200	432,000	13.9:1
30/40 Mesh	70.0	70.4	1,740	3,490	2.0:1	10,400	81,250	7.8:1
40/50 Mesh	88.8	87.3	719	1,470	2.1:1	6,160	53,[illegible]00	8.7:1
50/60 Mesh	139.0	128.0	366	1,360	3.7:1	2,270	26,700	11.8:1

*Calculated areas based on average particle diameter as determined by air permeability (Table 3, p 20) assuming all particles to be spherical.

**Surface areas determined using krypton as the adsorbing gas.

***Surface areas determined using nitrogen as the adsorbing gas.

TABLE 12

Performance characteristics of compositions containing balled and atomized magnesium, Test I**

Item No.	Candlepower Average, 10^3 Candles FY-1230A A*	FY-1231 B*	Candlepower/sq. in., 10^3 Candles FY-1230A A	FY-1231 B	Burning Rate, in./min FY-1230A A	FY-1231 B	Efficiency Candleseconds/g × 10^3 FY-1230A A	FY-1231 B	Efficiency Candleseconds/cc × 10^3 FY-1230A A	FY-1231 B
1	121.5	111.4	87.4	79.5	5.0	5.0	36.4	34.4	63.5	59.3
2	121.8	115.7	87.6	83.0	5.0	5.1	36.0	35.6	63.0	60.8
3	93.1	117.1	70.6	84.3	5.0	5.4	29.2	33.2	51.0	57.2
4	106.9	117.4	76.8	84.5	4.9	5.0	32.4	36.0	56.6	62.0
5	109.5	126.0	78.8	90.8	5.0	5.2	32.4	36.8	56.6	63.3
6	101.8	115.7	73.2	83.0	5.2	4.8	29.2	37.2	51.0	64.0
7	99.8	126.8	71.8	91.2	5.2	4.9	28.4	39.1	49.6	67.5
8	102.3	121 6	73.8	87.4	5.2	4.9	29.6	38.4	51.7	66.2
9	117.9	139.0	84.6	100.0	5.1	5.3	34.0	40.6	59.4	69.6
10	112.7	133.7	81.0	96.1	4.9	5.1	34.0	40.0	59.4	68.9
Average	109.2	122.7	78.6	88.0	5.1	5.1	32.2	37.1	56.2	63.9
Standard Deviation × 10^3	9.1	8.8	9.3	6.5	.192	.13	2.9	2.4	5.1	4.1
Coefficient of Variation, %	8.3	7.3	11.8	7.4	3.8	2.6	9.0	6.4	9.1	6.4

*A = atomized, B = balled.

**Composition: Magnesium/sodium nitrate/ Laminac 56/3[illegible].3/7.7.
FY-1230, Atomized, Lot No. DA-28-017-A-5-0836-5A, Drum 14
FY-1230A, Atomized, Lot No. DA-28-019-A-5-0729-1A, Drum 3
FY-1231, Balled, Lot No. RMC-305, Drum 32.

TABLE 13

Performance characteristics of compositions containing balled and atomized magnesium, Test II***

Item No.	Candlepower Average, 10^3 candles FY-1230 A*	FY-1230A A	FY-1231 B	Candlepower/sq. in., 10^3 candles FY-1230 A	FY-1230A A	FY-1231 B	Burning Rate, in./min FY-1230 A	FY-1230A A	FY-1231 B	Efficiency Candleseconds/g × 10^3 FY-1230 A	FY-1230A A	FY-1231 B	Efficiency Candleseconds/cc × 10^3 FY-1230 A	FY-1230A A	FY-1231 B
1	127.1**	120.8	138.5**	91.4**	86.8	99.6**	4.7**	5.0	5.3**	40.8**	36.0	40.0**	71.4**	63.0	69.0**
2	126.0	141.7	151.8	70.6	101.8	109.0	5.0	5.0	5.0	37.6	42.4	46.4	65.8	74.2	80.0
3	141.3	144.5	132.5	101.6	103.8	95.4	5.1	5.4	4.8	41.2	40.0	42.4	72.0	70.0	73.2
4	131.6	145.6	131.6	94.8	105.4	96.8	4.9	5.4	4.6	38.2	40.0	45.2	67.0	70.0	77.8
5	131.5	144.3	154.4	94.5	103.6	110.1	5.3	5.3	5.3	36.8	40.4	38.8	64.2	70.6	66.8
6	148.1	128.4	157.4**	[illegible]	92.4	112.8**	5.3	5.1	5.9**	39.1	38.6	40.8**	68.4	65.6	70.4**
7	140.8	136.8	141.2	101.2	98.2	101.5	5.1	5.1	5.5	40.8	40.0	39.2	71.4	70.0	67.6
8	131.4	147.0	146.5	94.5	105.6	105.2	4.9	5.3	5.3	40.0	42.4	42.0	70.0	74.2	72.4
9	137.2	144.6	141.1	98.8	104.0	101.5	4.9	5.4	4.9	41.6	39.6	44.4	72.8	69.2	76.5
10	143.5	146.9	135.4	103.2	105.5	97.5	5.4	5.4	5.0	39.6	40.0	41.6	69.2	70.0	71.8
Average	136.7	140.1	142.2	98.3	100.7	102.1	5.1	5.2	5.1	39.4	39.9	42.5	68.9	69.7	73.3
Standard Deviation × 10^3	6.7	9.3	8.1	5.1	6.2	5.5	.19	.18	.31	1.7	1.8	2.7	2.9	3.4	4.5
Coefficient of Variation, %	4.2	6.6	5.7	5.2	6.2	5.4	3.7	3.5	6.1	4.3	4.5	6.4	4.2	4.9	6.1

*A = atomized: B = balled.

**Not included in averages, fell into pit and burned.

***Composition: Magnesium/sodium nitrate/Laminac 56/36.3/7.7.
FY-1230, Atomized, Lot No. DA-28-017-A-5-0836-5A, Drum 14
FY-1230A, Atomized, Lot No. DA-28-019-A-5-0729-1A, Drum 3
FY-1231, Balled, Lot No. RMC-305, Drum 32.

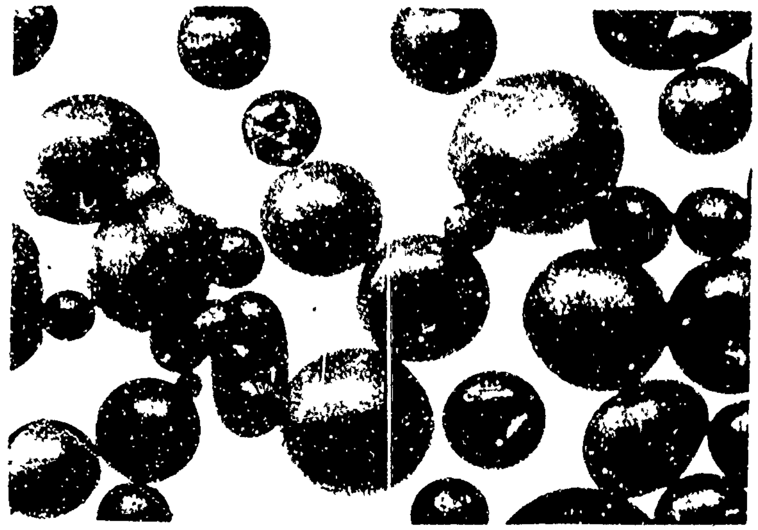
TABLE 14

Performance characteristics of compositions containing balled and atomized magnesium, Test III**

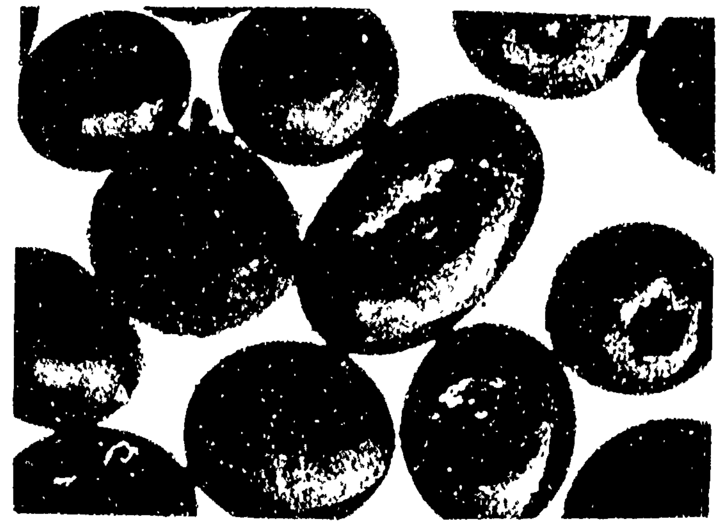
Item No.	Candlepower Average, 10^3 candles FY-1230 A*	Candlepower Average, 10^3 candles FY-1230A A	Candlepower Average, 10^3 candles FY-1231 B	Candlepower/sq. in., 10^3 candles FY-1230 A	Candlepower/sq. in., 10^3 candles FY-1230A A	Candlepower/sq. in., 10^3 candles FY-1231 B	Burning Rate, in./min FY-1230 A	Burning Rate, in./min FY-1230A A	Burning Rate, in./min FY-1231 B	Efficiency Candleseconds/g $\times 10^3$ FY-1230 A	Efficiency Candleseconds/g $\times 10^3$ FY-1230A A	Efficiency Candleseconds/g $\times 10^3$ FY-1231 B	Efficiency Candleseconds/cc $\times 10^3$ FY-1230 A	Efficiency Candleseconds/cc $\times 10^3$ FY-1230A A	Efficiency Candleseconds/cc $\times 10^3$ FY-1231 B
1	122.2	114.4	144.7	88.0	82.4	101.2	4.7	5.5	5.2	38.4	30.8	45.2	67.2	53.8	77.8
2	128.3	118.9	127.2	92.4	85.6	91.8	4.8	5.4	4.9	39.2	32.4	39.6	68.5	56.6	68.2
3	127.5	122.1	122.9	91.8	83.8	88.2	4.8	4.9	5.0	40.0	37.2	37.6	69.8	65.1	64.8
4	124.2	125.1	126.3	89.2	90.0	91.0	4.8	4.9	5.0	38.4	38.0	39.2	67.2	66.2	67.6
5	123.6	126.3	122.8	88.8	90.8	88.2	4.5	5.2	5.0	40.3	36.0	38.0	70.6	63.0	65.5
6	124.1	124.3	142.0	89.2	89.4	102.2	4.7	4.9	5.1	39.6	37.2	42.4	69.2	65.1	74.2
7	127.3	123.8	141.6	91.6	89.0	101.8	4.7	4.9	5.0	40.3	37.6	40.8	70.6	65.6	71.3
8	129.2	123.0	142.0	92.8	88.5	102.2	4.9	5.0	5.3	39.2	36.4	41.2	68.5	63.6	72.2
9	132.8	125.3	143.2	95.6	90.2	103.2	5.1	5.1	5.3	38.8	36.4	41.2	67.8	63.6	72.2
10	133.0	114.3	133.7	95.6	82.2	96.7	4.7	4.8	4.9	40.8	35.6	41.2	71.3	61.5	72.2
Average	127.2	121.8	134.6	91.5	87.7	96.9	4.8	5.1	5.1	39.5	35.8	40.6	69.1	62.4	70.6
Standard Deviation $\times 10^3$	3.8	4.4	9.2	2.8	3.2	6.5	.16	.24	.15	.83	2.3	2.2	1.5	4.1	4.0
Coefficient of Variation, %	3.0	3.6	6.8	3.1	3.6	6.7	3.3	4.7	2.9	2.1	6.4	5.4	2.2	6.6	5.7

*A = atomized: B = balled.

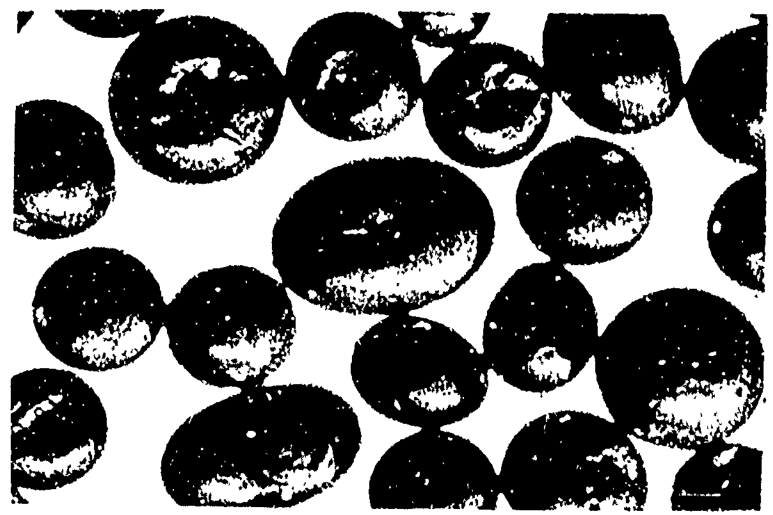
**Composition: Magnesium/sodium nitrate/Laminac 56/36.3/7.7.
FY-1230, Atomized, Lot No. DA-28-017-A-5-0836-5A, Drum 14
FY-1230A, Atomized, Lot No. DA-28-019-A-5-0729-1A, Drum 3
FY-1231, Balled, Lot No. RMC-305, Drum 32.



Total sample 30/50 mesh

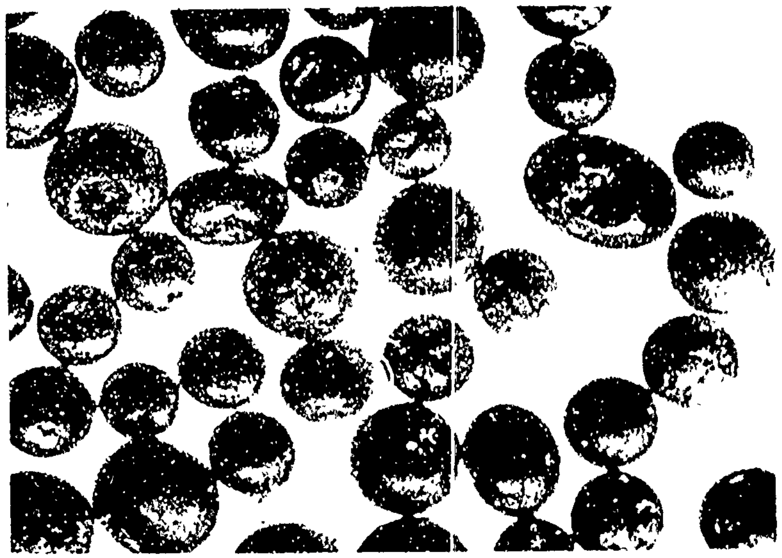


20/30 mesh sieve fraction

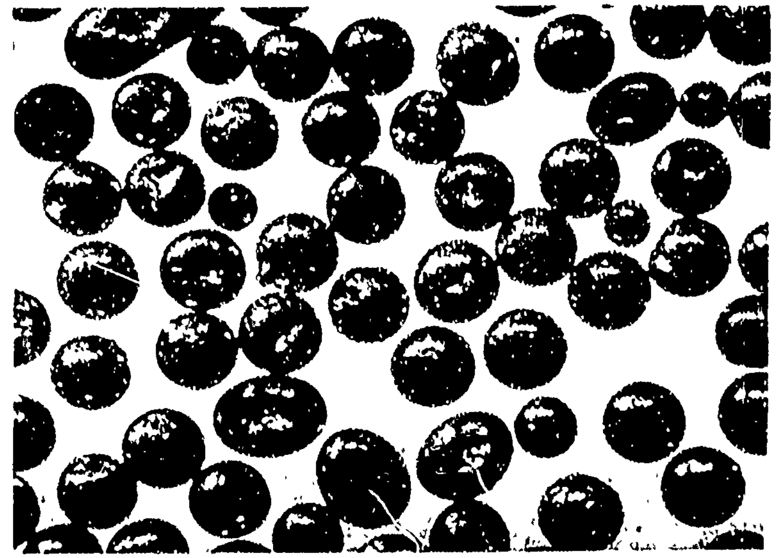


30/40 mesh sieve fraction

Fig 1 Photomicrographs of powdered atomized magnesium at 35 × magnification

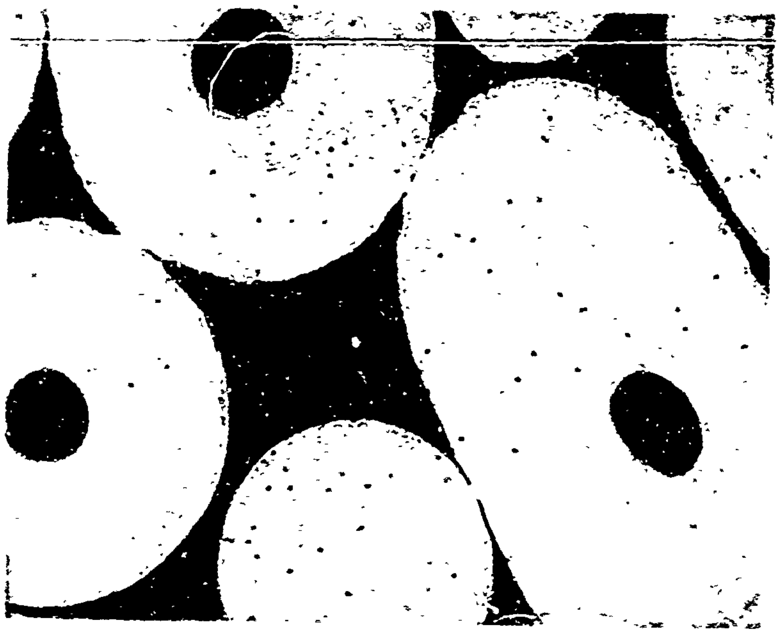


40/50 mesh sieve fraction

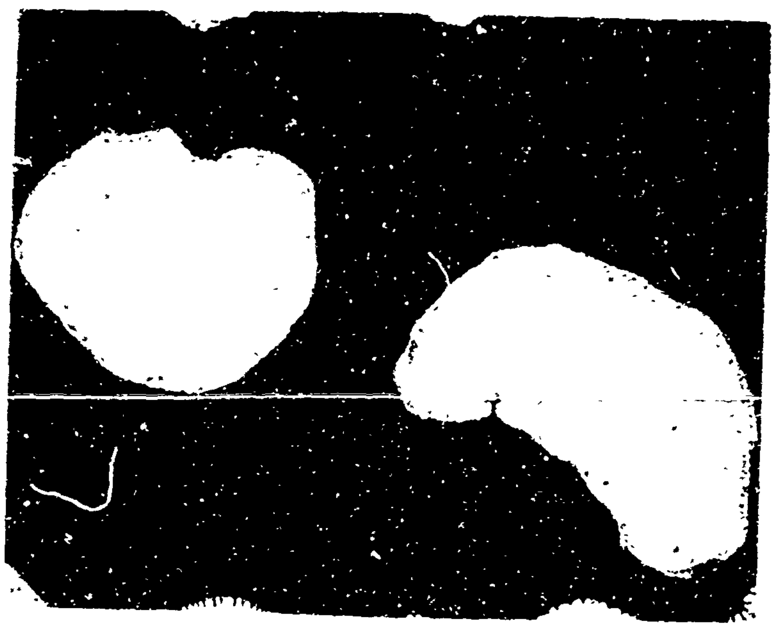


50/60 mesh sieve fraction

Fig 1 (cont)



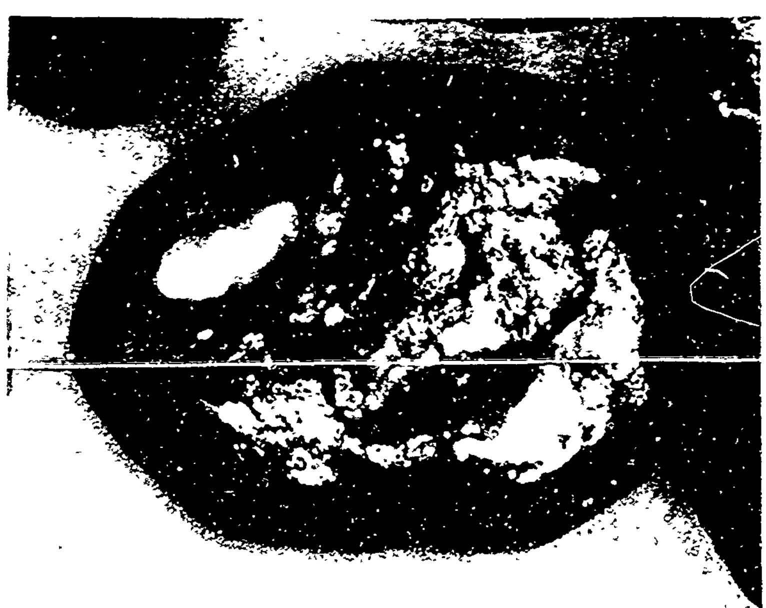
Atomized magnesium particles



Balled magnesium particles

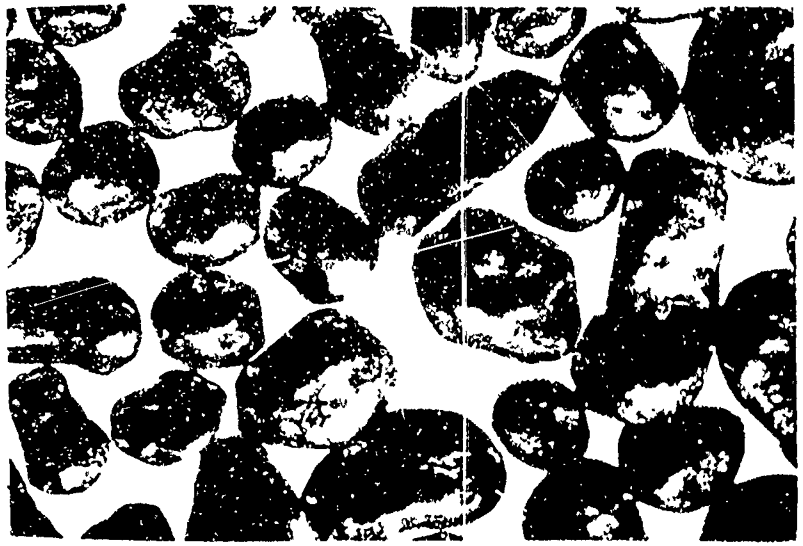
Fig 2 Cross-sectional photomicrograph of typical balled and atomized magnesium particles at 75 × magnification

Atomized magnesium particle



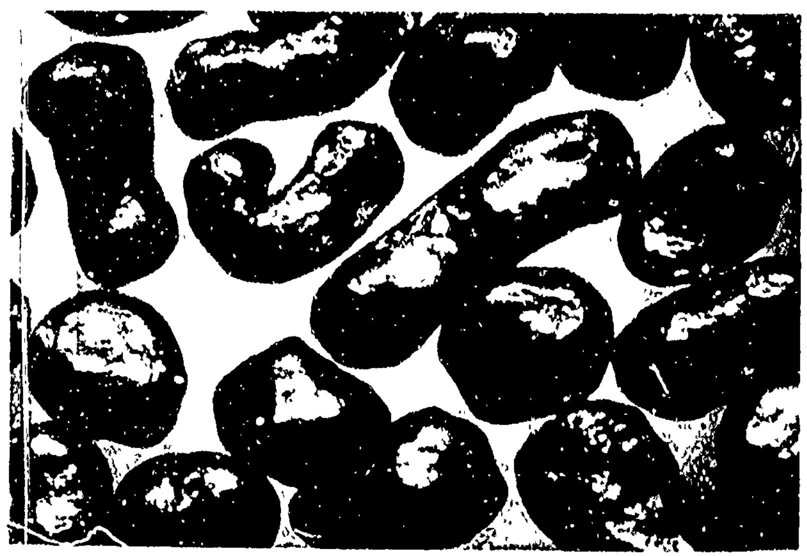
Balled magnesium particle

Fig 3 Photomicrograph of typical single balled and atomized magnesium particles at 75 × magnification



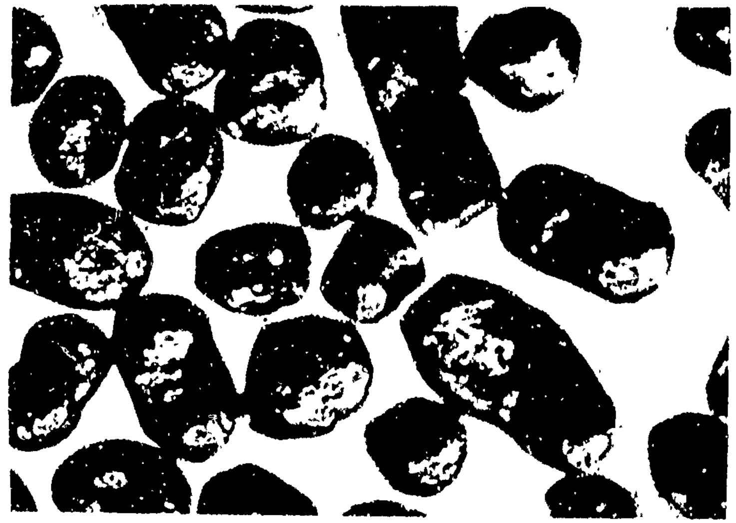
Total sample 30/50 mesh

20/30 mesh sieve fraction



30/40 mesh sieve fraction

Fig 4 Photomicrographs of powdered balled magnesium at 35 × magnification



40/50 mesh sieve fraction

50/60 mesh sieve fraction

Fig 4 (cont)

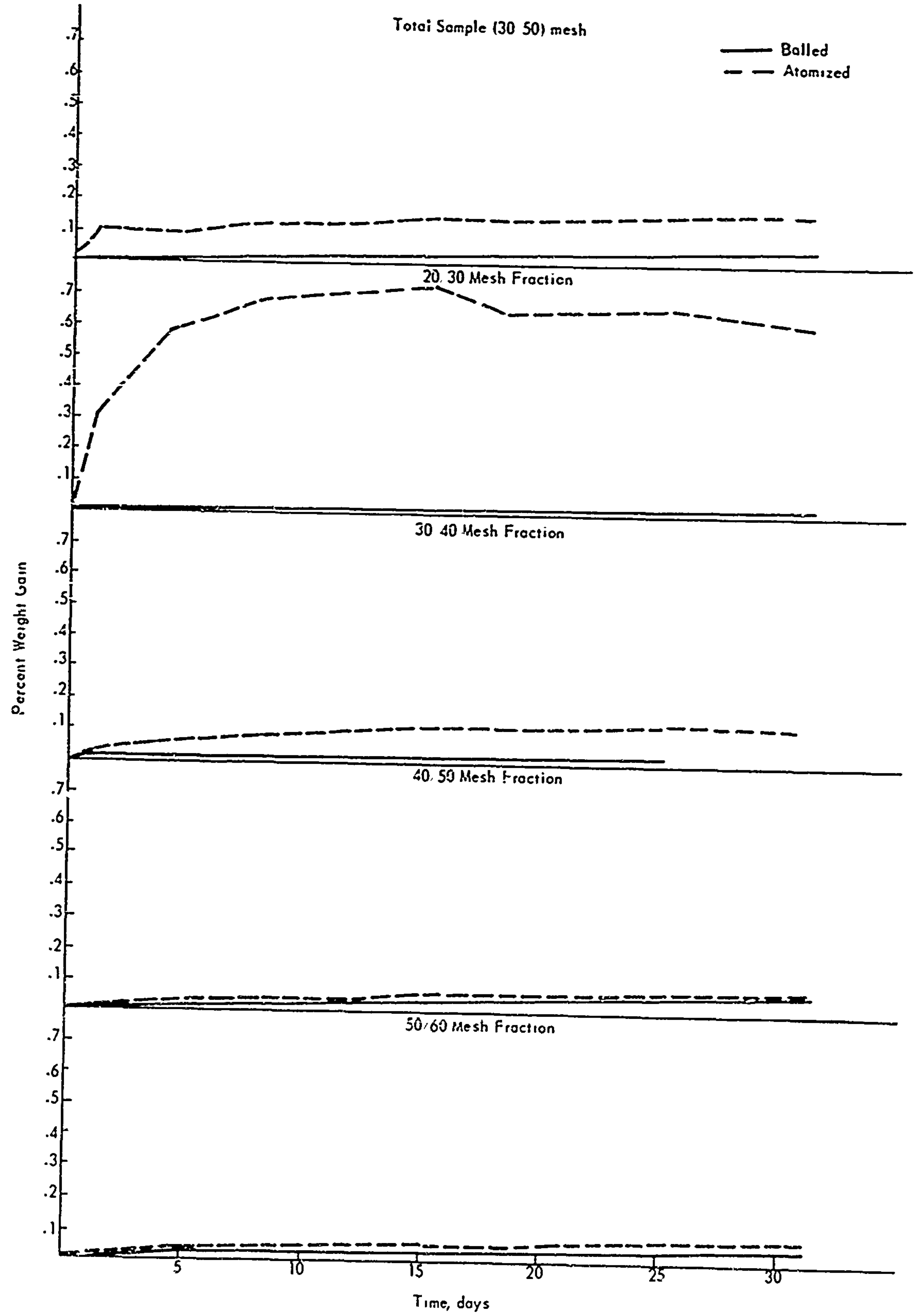


Fig 5 Percent weight gain at 70% relative humidity 30°C of balled and atomized magnesium

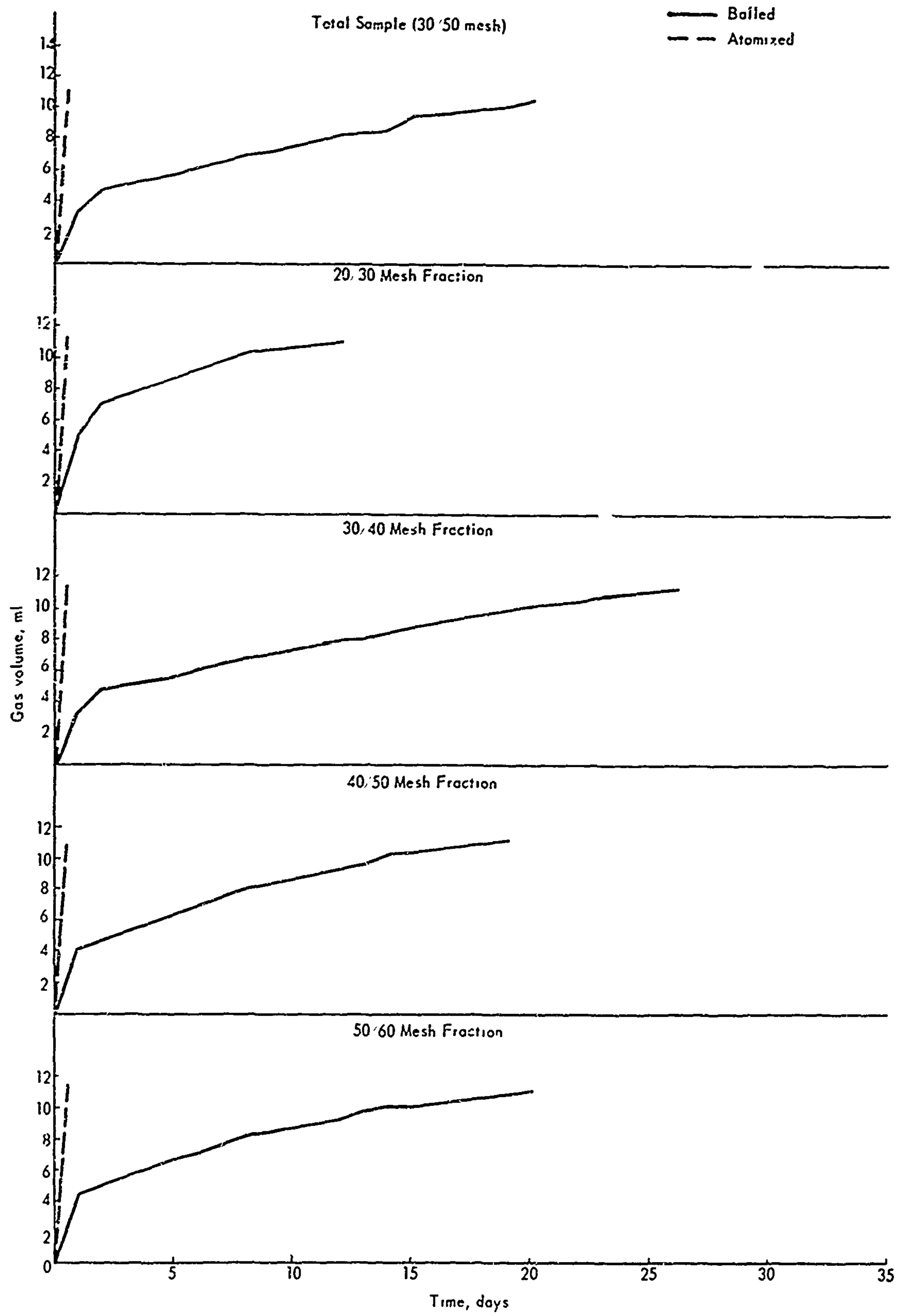


Fig 6 Reactivity with water at room temperature of balled and atomized magnesium

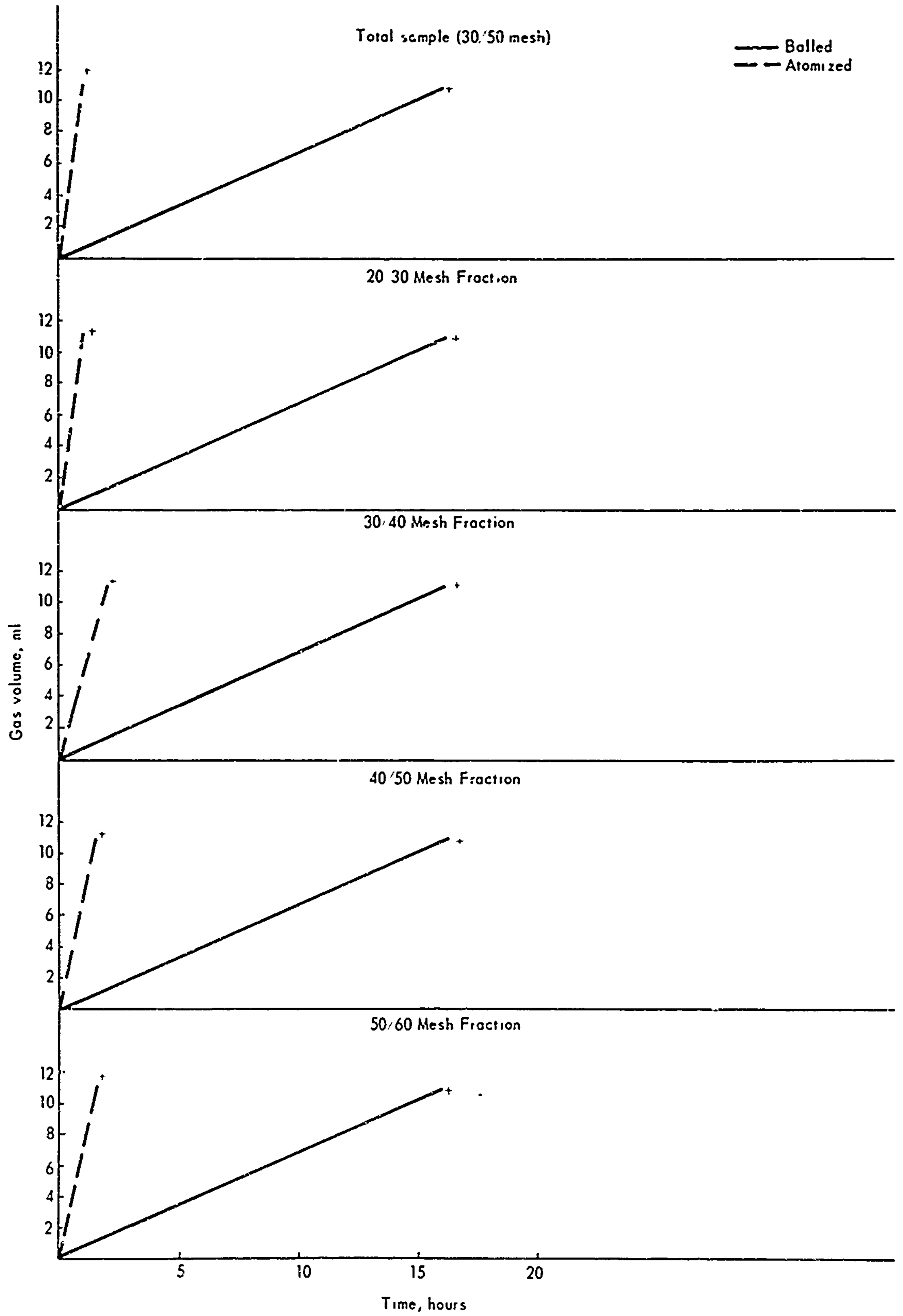


Fig 7 Reactivity with water at 76°C (167°F) of balled and atomized magnesium

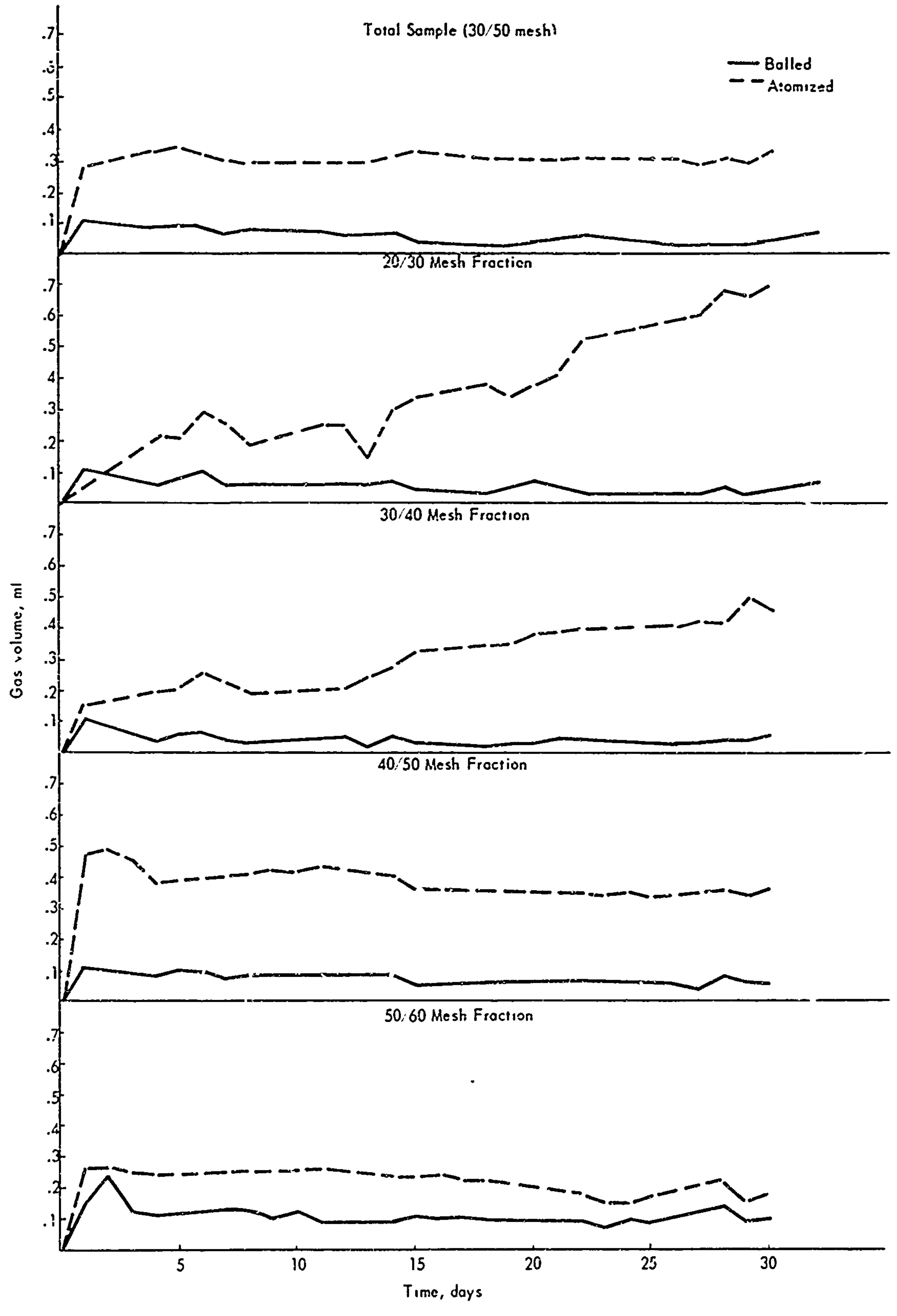


Fig 8 Vacuum stability at 76°C of balled and atomized magnesium

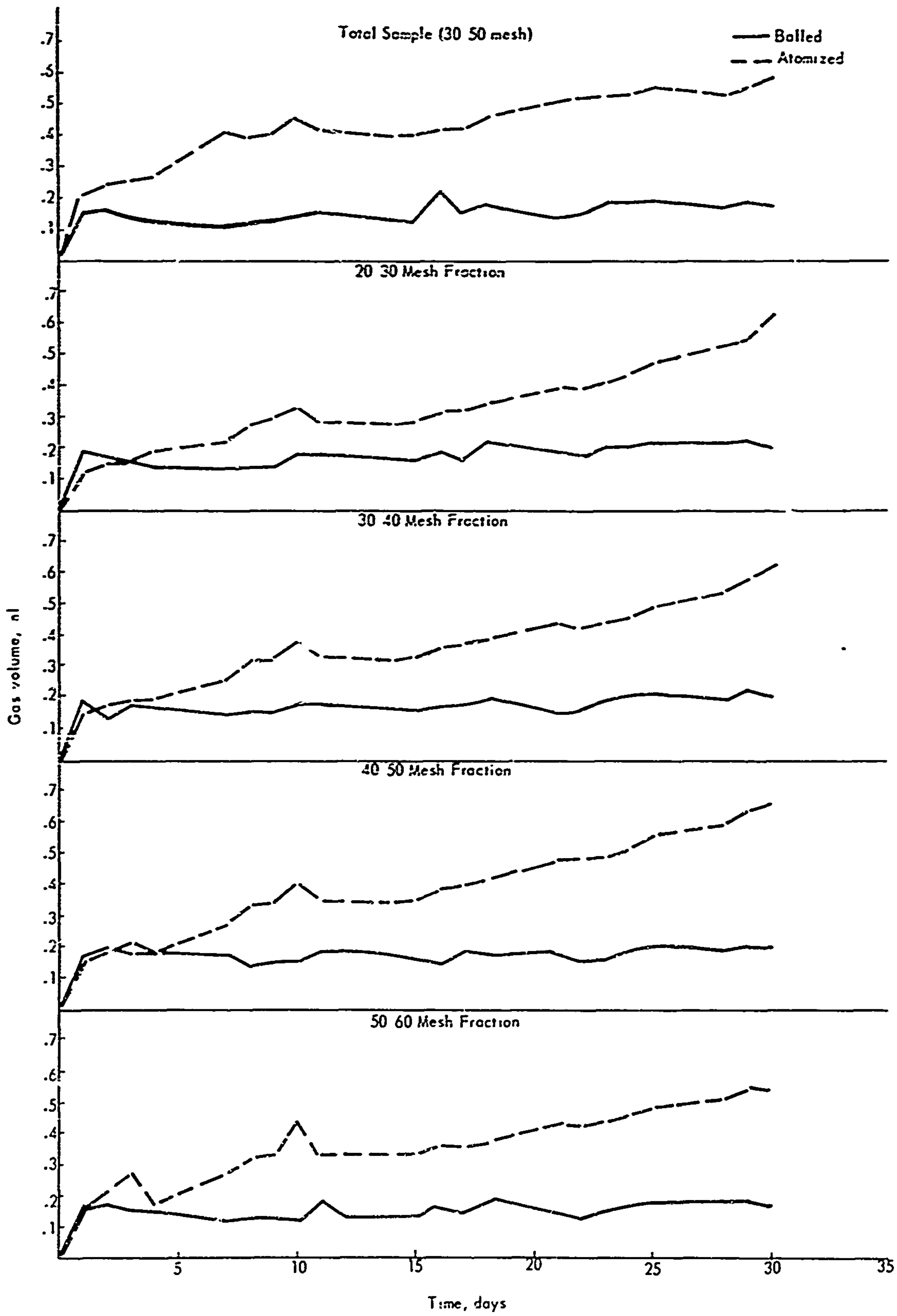


Fig 9 Vacuum stability at 110°C of balled and atomized magnesium

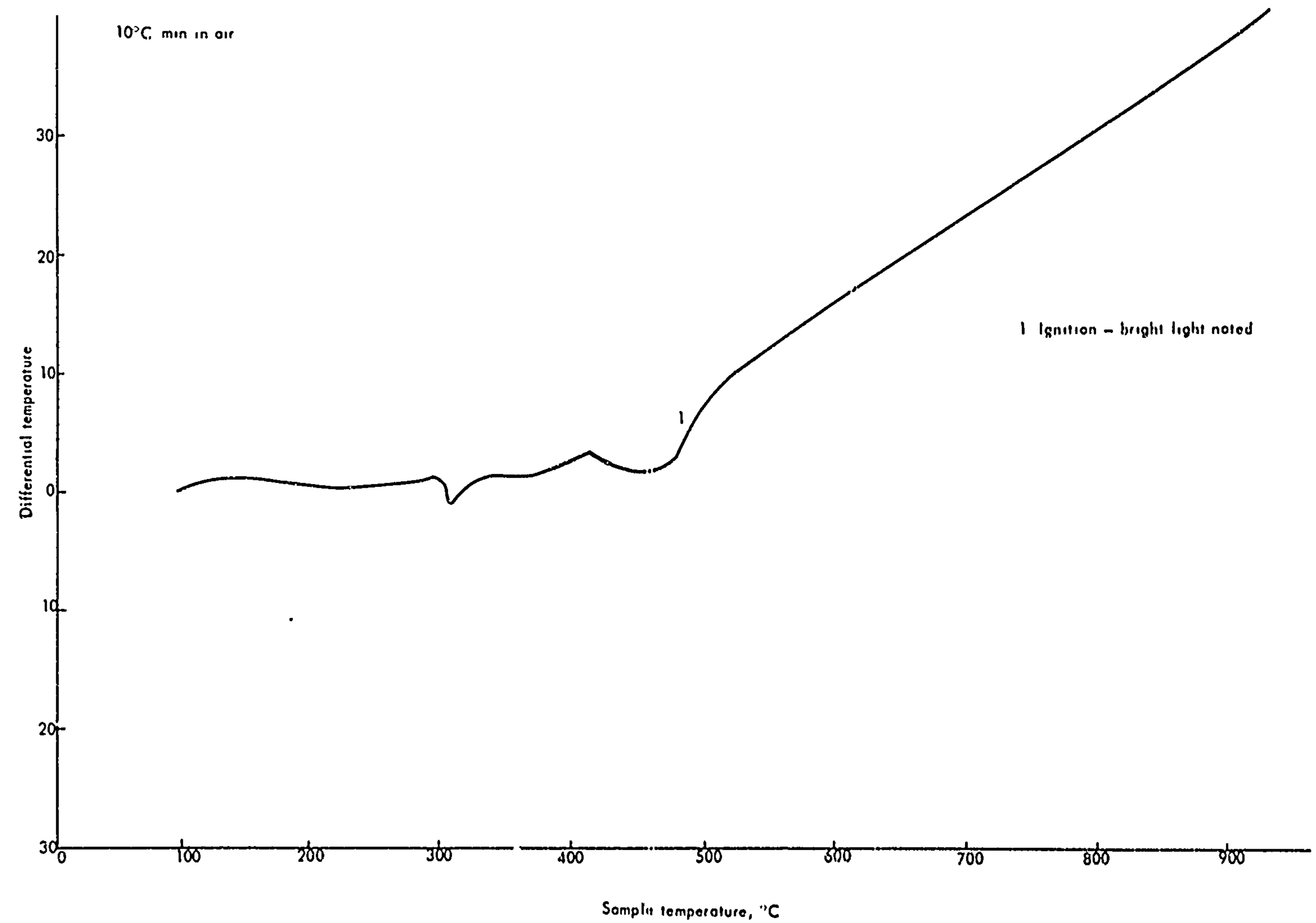


Fig 10 Differential thermal analysis of pyrotechnic composition* prepared with atomized magnesium

*Composition:	Mg, 30/50, atomized	56.0%
	Sodium nitrate, 34 microns	36.3%
	Laminac 4116	7.7%

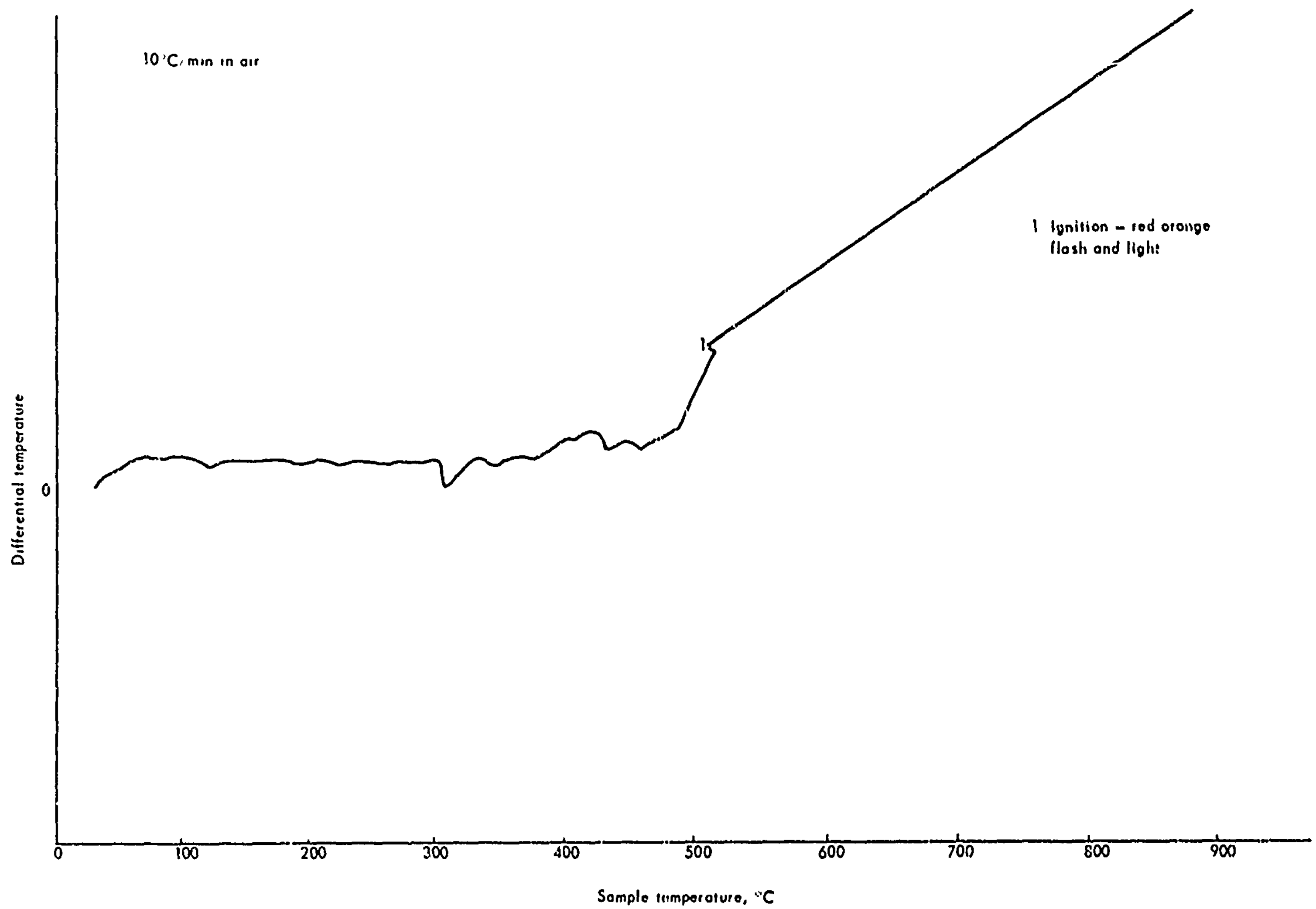


Fig 11 Differential thermal analysis of pyrotechnic composition* prepared with balled magnesium

*Composition:	Mg, 30/50, balled	56.0%
	Sodium nitrate, 34 microns	36.3%
	Laminac 4116	7.7%

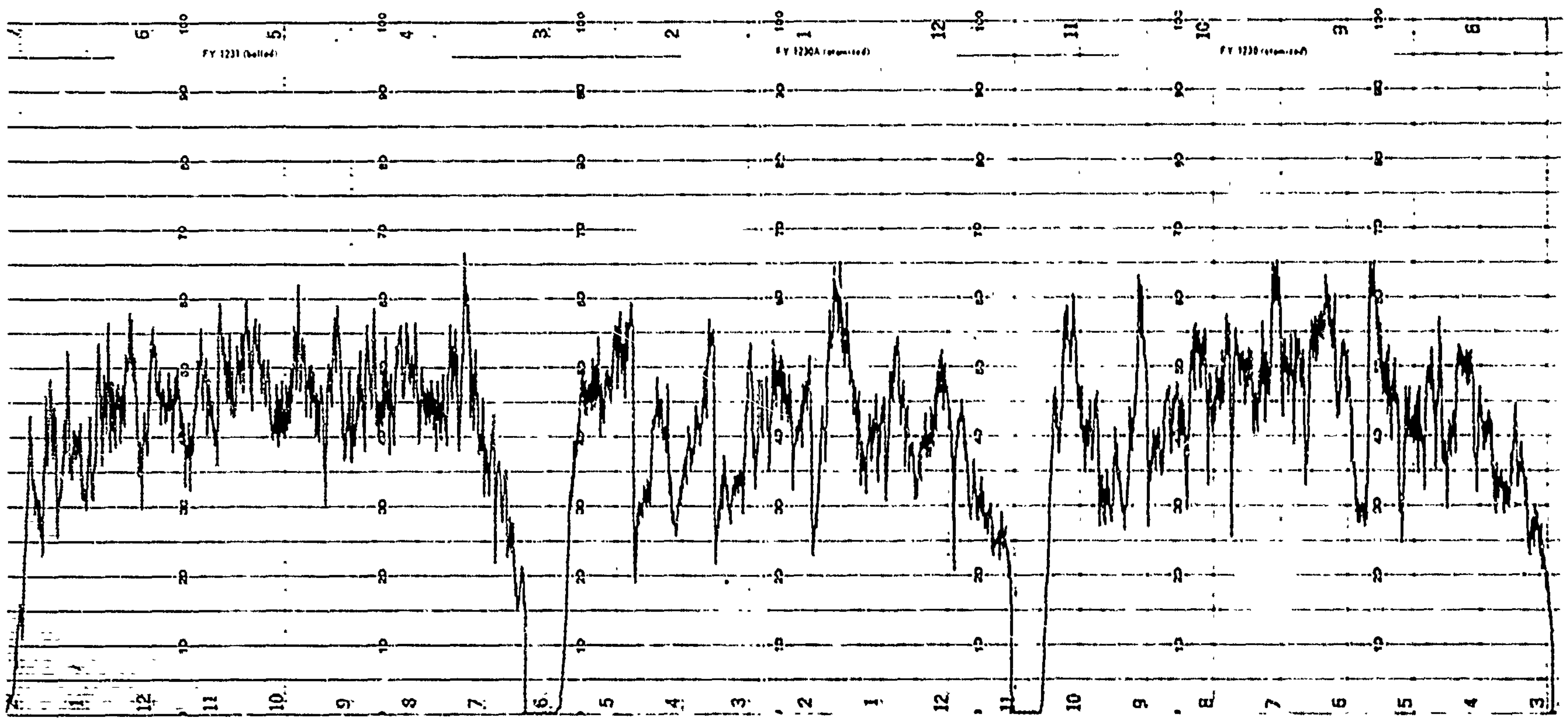


Fig 12 Typical luminous intensity vs time traces of compositions containing atomized and balled magnesium

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Results of a variety of physical and chemical tests indicate that, with a few minor exceptions, Reade (balled) magnesium meets the requirements of Military Specification 14067-A for 30/50 mesh magnesium powder. The balled magnesium has been found to be less reactive than the currently prescribed atomized magnesium, both with water and as a result of exposure to high relative humidities, as determined by gas evolution, weight gain, and surface area measurements. Results of vacuum stability tests at 167°F and 230°F for thirty days indicate that the balled magnesium has greater stability than atomized magnesium; the thermochemical and sensitivity data for balled magnesium and atomized magnesium are comparable. In performance characteristics such as candlepower, burning rate, and luminous efficiency, similar results were obtained with the two materials. These results indicate that the Reade balled magnesium can be used as an alternate for Valley atomized 30/50 mesh magnesium in consolidated pyrotechnic compositions.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Pyrotechnics						
Mechanically balled magnesium						
Atomized magnesium						
Vacuum stability tests						
Candlepower						
Burning rate						
Luminous efficiency						
Thermochemical data						
Particle size distribution						
Heat of combustion						
Sensitivity						

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